1878

The production of spelter from zinc blende

Lee R. Grabill

A

THESIS

SPELTER FROM ZINC BLENDE

GRABILL

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JUNE, 1878.

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Problem for Examination in Metallurgy.

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Missouri School of Mines & Metallurgy.
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Analyses of the materials used are to be given with details of processes and drawings & descriptions of machinery used; also approximate cost of furnaces, and approximate cost of production.

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I.

General discussion of the treatment of blende ores. ------------

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The mineral, known as Sphalerite or Blende to the mineralogist, and as "black-jack" to the miner, is the sulphide of zinc: It contains, in its pure state, 67.08% zinc, and 32.92% sulphur. As an ore, however, it is rarely found in a state of purity; there being usually mixed with it the sulphides of iron, lead, copper, and antimony, and more rarely those of bismuth and cadmium. It has a resinous color and luster. Its hardness is 3.5 to 4, and it has a specific gravity of 3.5 to 4.2.

The treatment of this ore is the most difficult problem involved in the treatment of zinc ores. For before beginning the reduction of the ore, it must first be prepared by roasting thoroughly, the object being to drive off as nearly as possible all the sulphur. For this reason, blende ores are less often treated, and bring a lower price in the market, than carbonate and silicate ores.

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phur and driving it off as sulphurous acid, at the same time oxidizing the zinc. In this operation it is impossible to avoid the formation of a small quantity of sulphate of zinc; This requires for its decomposition a bright red, — nearly white — heat. It is not most economical in roasting to render the ore perfectly free from sulphur, as the complete decomposition of the sulphate would require a too great expenditure of time and fuel. The roasting is usually accomplished in reverberatory furnaces.

Zinc volatilizes at the temperature of 1200° Centigrade. It is reduced from its oxyd at the temperature of °1300 Centigrade. It is necessary therefore that all operations having for their object the recovery of zinc from its oxyd by means of heat and deoxidizing agents, — as coal — must be processes of distillation, and the metal, being in a form of vapor when reduced, must be condensed.

There are three general methods practiced for this distillation process, known as the Belgian, Silesian, and English, from the various countries in which they were formerly practiced. The only one in use in this country is the Belgian, as it is best suited to the economical conditions existing here, viz:— high priced la-

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for and cheap coal. This method has therefore been adopted in this problem, and the practice at the Works of the Lehigh Zinc Company, Bethlehem, Pennsylvania, has been followed more nearly than any other for the processes, though not too closely.

The necessities of the Belgian process are, besides a good ore, clay for the manufacture of distilling and condensing vessels, and coal for fuel and also for a reducing agent. In order that the spelter made should successfully compete with that from carbonate & silicate ores, the blende should be of excellent quality, nearly free from gangue, and not containing much iron nor lead, particularly the latter.

The clay required in the Belgian method is a fireclay of the first quality; since a poor clay, being incapable of withstanding the great heat required, makes retorts which are liable to crack or fuse, and causes loss of zinc.

The coal used for the reduction of the oxyd should be a non-caking coal, and should contain but little bituminous matter or hydrogen compounds, as these in burning form vapor of water, which oxidizes the zinc already reduced. Coke is frequently employed, mixed with an equal weight of bituminous coal, but an anthracite or semi-anthracite answers the purpose equally well.

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The economical conditions required for the production of zinc from a blende are an abundant supply at a low price of a rich and pure ore, with cheap transportation to coal. The amount of coal required being greater than the weight of ore treated, the ore is nearly always carried to the coal for treatment.

The uses of spelter are now so numerous as to give this metal a steady market price. Among its various applications are its use as a roofing metal, its many uses in the form of sheet zinc, the so-called "galvanized" iron, etc, besides others of less importance.

A good spelter should contain little of any other metal. Arsenic, antimony, and tin render zinc brittle. A large amount of cadmium has this effect also. .13 to .14% of iron does not injure zinc, but a greater quantity renders it more easily corroded. Lead injures the firmness of a zinc very much. The most injurious constituents may be said to be arsenic, antimony, and lead.

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A good spelter should contain little of any other metal. Arsenic, antimony, and tin render zinc brittle. A large amount of cadmium has this effect also. 13 to 14% of iron does not injure zinc, but a greater quantity renders it more easily corroded. Lead injures the firmness of a zinc very much. The most injurious constituents may be said to be arsenic, antimony, and lead.

II.

Discussion of the materials used.

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The ore to be treated, as stated, is a blende from Sevier County, Southwestern Arkansas. The mine from which it is taken is known as the Davis mine and yields quantities of galenite and ores of antimony. The blende is probably found in the subcarboniferous rocks, like the galena & blende of southwestern Missouri. A railroad line running to Little Rock is not far distant. The analysis of this ore made by myself in the laboratory of the school, is as follows: —

Zn,	61.868
S,	31.389
Fe,	2.193
Sb,	.032
Cu,	.032
SiO_2	4.270
$CaOCO_2$	.007
$MgOCO_2$	.193
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The foreign metals probably exist as sulphides. It will be seen that the only impurities present in notable quantities are silica, as gangue, and iron, probably existing as FeS_2. The quantity of silica would have scarcely any effect on the zinc, as no appreciable amount of it is carried out of the retort. The iron, on the other hand, is present in rather large quantity, but would not render the zinc more impure than several spelters known; for instance (vide Geological Survey of Missouri, 1875-6, p. 117), the zinc of the Missouri Company at Carondelet contained .7173 iron.

Estimating that after roasting the roasted ore contains 2% of its weight in sulphur, — and this is as low as average results of roasted blende show — we find that we will have 30% of sulphur driven off from the raw ore by roasting. The roasted ore will weigh 70% of the weight of the raw ore and will have the following composition, calculated:—

CaO	.05
MgO	.13
$ZnSO_4$	10.07
SiO_2	6.10
Fe_2O_3	4.33
Sb_2O_5	.03
CuO	.06
ZnO	79.23

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The percentage of zinc in the roasted ore will be 67.75. In the above calculation it was assumed that ½ the antimony would be driven off in roasting. 14 tons of roasted ore corresponding to this analysis would be produced by roasting 20 tons <u>raw ore.</u>

The clay.

The clay assigned for the construction of retorts is that mined by Parker, Russell & Co., of Oakhill, near St. Louis, and used by them in the manufacture of fire-brick, at Cheltenham.

It is of a gray color, owing to the presence of organic matter, but becomes white on burning. The following extract in reference to the clay is made from the Geological Survey of Missouri, 1875-6:—

"The fire-clay is an irregularly-stratified, wavy formation, and is found only at one single place in the whole property, where it seems to have a mere local development. It is not known between which of the regular strata the clay lies, because the shaft has been dug through old mining materials. Where the clay was found, no coal was found."

The geological location of the clay is in the coal-measures.

An analysis made of this clay gave me the following result:—

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SiO_2,	63.390
Al_2O_3,	22.746
FeO,	.818
CaO,	.223
MgO,	.053
Na_2O,	.889
Water of Composition	7.996
Organic matter	.184
Hygroscopic water	3.273
Sulphur	.276
Phosphorus	(trace in 0.48 grm.)

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For qualities, this clay compares well with the Stourbridge clay well known as an excellent fire-clay. It is used for making the retorts of the South St. Louis and Carondelet zinc works, and is there used in the proportion of two of clay to one of chamotte.

The clay makes an excellent firebrick, as it contains very small quantities of those bases which combine with silica to easily fusible compounds, viz:— FeO, CaO, MgO, K_2O & Na_2O.

Further particulars as to retorts will be given further on.

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Coal.—

The coal assigned to be used as fuel is the ordinary flaming coal of St. Louis and vicinity. It is a bituminous caking coal with a long flame, giving a large quantity of gases; and is very serviceable for heating the distilling furnaces, as well as the roasting furnaces. The analysis is as follows:— [It will be seen that the sample contained a large quantity of hygroscopic moisture, possibly from having been left in a damp place.]

Hydroscopic moisture,	8.395
Volatile matters,	34.158
Fixed Carbon,	41.962
Ash, (Grey)	9.485
	100.000

It will be seen that this is a good ordinary fuel coal, and is particularly adapted to burning in a gas producer, from the large amount of volatile products which it gives on burning.

The coal to be used as a reducing agent is the Spadra coal, from Johnson county, Arkansas. This is a coal remarkable for its excellent qualities, although the vicinity is said to show no signs of upheaval or other igneous action, it is a semi-anthracite, being hard, and containing a very small amount of volatile matters, and a large amount of fixed carbon. It is easily broken or crush-

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into fragments, without forming dust. It leaves a small amount of ash, in color a light reddish brown. What is remarkable, the sample taken for analysis contained no weighable sulphur in 0.67 grm. It is sold in St. Louis for $5.00 p. ton. It is very good as a reducing agent, especially in zinc distillation; as, containing little hydrogen, it will form little water in burning. [In using common coal it is found best to mix it with an equal weight of coke; for the water formed is likely to oxidize the zinc vapors present, forming the "blue powder", which must be treated again.] The coal has no tendency to cake, but remains in the form of small grains, allowing free circulation of gases. The following is the analysis:—

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Quality of Zinc produced.—

The changes which will take place can not with certainty be predicted. With the above analyses, if we had an analysis of the residue, we could give to a certainty the analysis of the resulting spelter: But we do not know how much zinc will be present in the residue as oxyds and how much as sulphate, or in the metallic form.

From the examination of analyses of other residues, from retorts, we find that they contain, as would be expected, the ashes of the coal, the silica of the ore, with the lime, magnesia, and part of the iron, copper, antimony, and sulphur, with unvolatilized zinc and zinc oxyd.

Comparing the analyses of the roasted ores of the works at Carondelet with the analyses of the two resulting spelters (vide Mo. Geological Survey, 1875-6), the following conclusions were deduced: That, on the average, the percentage of iron found in the spelter is 1/6 the percentage found in the roasted ore; in like manner the percentage of antimony in the spelter is 1/3; of sulphur, 1/12; of silica, $\frac{1}{375}$ that found in the roasted ores. Also that the percentage of carbon varies from .2 to .0006 of 1%. With these conclusions and the analysis of the roasted blende (see previous pages) as data we find that the analysis of the spelter will probably be something near that given on the next page.

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SiO_2,	.0352
S	.3333
Fe,	1.0103
Sb	.0146
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Zn,	98.4568
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148.7 cwt. zinc would be the average yield of 20 tons of raw ore, this being 70 % of the total amount of zinc in the roasted ore. This yield is low. [Seventy per cent of the theory is said to be the yield at Carondelet; but of the remaining 30 per cent, part is afterward saved by retreating the skimmings & fumes.]

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III.

Complete details of operations and machinery.

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The ore is taken from the mines in size from the largest pieces that can be easily handled, down. It is sorted by hand when taken out of the mine; the pieces consisting alone of worthless gangue being thrown away, while the pieces of ore are left.

It is then placed in iron cars and conveyed to the roasting heaps. These heaps contain 50 tons, being 26½ ft. in length, 14½ in breadth, and 8 ft. in height. The heap is built over an iron grate supported on two lateral walls, 1½ ft. thick, each, and one central wall 3 ft. thick, all of stone. Wood placed beneath the grates is used for firing. This preliminary roasting is for the purpose of softening and drying the ore previous to crushing, as well as to drive off some sulphur.

The ore is after this roasting shipped to its destination, which should be the nearest place supplying abundant fuel coal of good quality.

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The ore is after this roasting shipped to its destination, which should be the nearest place supplying abundant fuel coal of good quality.

Here the ore is unloaded from the cars directly on to the crushing floor.

It is passed through a Blake's crusher, which crushes it to pieces of the size of an inch cube, and less.

This machine is in such common use as hardly to require description. The crushing is effected by two adjacent and slightly converging surfaces which are made to alternately approach and recede from each other through the agency of toggle-joint motion. The fly-wheel shaft (See fig 1.) is placed on the frame of the crusher directly above the center of the toggle joint. An eccentric placed on the shaft works the pitman F, against which the two toggle plates GG are hinged. The other ends of these toggle-plates bear against the movable jaw J and the toggle-block O. It will readily be seen that the vertical motion of the pitman F will cause the jaw J to work about its center K through a short arc. The approach of the two jaws to each other can be regulated by raising or lowering the wedge N by means of the screw above it. The backward motion of the movable jaw J is insured by means of the rod M and the rubber spring L. The jaws are lined with corrugated face-plates of chilled iron, which are reversible; so that when their lower portions become worn they can be inverted.

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One of the smaller Blake Machines may be used, crushing about 5 tons per hour, and requiring 6-horse-power to work it at 150 to 200 vibrations per minute.

[Engineering and Mining Journal, Nov. 11, 1876.]

A 10-horse-power crusher is used at the Lehigh works.

In coming from the Blakes crusher the ore should fall on a floor, (see Fig 13), just at the level of which should be the hopper of the Cornish rolls. The ore, after passing through the Blake machine, is either heaped to one side on the floor, or shoveled directly into the hopper above the rolls (C).

The Cornish rolls (Figs. 2 & 3) are in common use for fine grinding. The form given is compact and any degree of compression can be given to the rollers by means of the caoutchouc buffers (A). The roller surface is of chilled iron, made as a ring, which is kept on the roller shaft by three wedge-bolts. The diameter of the rollers is 37 inches, the breadth 10 ½ inches, and they may make eight revolutions per minute. The velocity of the rolling surface would be, therefore, 77 ½ feet per minute; and the crushing area of each roller 68 sq. ft. per minute. The shafts carrying the rollers are geared with toothed wheels at each side; -- each roller working, -- not by friction, but by

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The Cornish rolls (Figs. 2 & 3) are in common use for fine grinding. The form given is compact and any degree of compression can be given to the rollers by means of the caoutchouc buffers (A). The roller surface is of chilled iron, made as a ring, which is kept on the roller shaft by three wedge-bolts. The diameter of the rollers is 37 inches, the breadth 10 ½ inches, and they may make eight revolutions per minute. The velocity of the rolling surface would be, therefore, 77 ½ feet per minute; and the crushing area of each roller 68 sq. ft. per minute. The shafts carrying the rollers are geared with toothed wheels at each side; -- each roller working, -- not by friction, but by

gear wheels. By being geared, a better grip is secured, and the action is altogether more steady and regular. The toothed wheels have teeth unusually long, so as to keep in gear if the rollers should become separated by the accidental passage of a large and hard piece of ore or stone. With such rollers in fair order, five tons per hour may be treated. The ore is fed into the hopper (a) by one man, and falls on the rollers, which revolve towards each other, in opposite directions. The rollers should be so adjusted that the ore is crushed to a fineness sufficient to allow it to pass through a sieve with 10 holes to the linear inch, or 100 holes per square inch. To insure this fineness, the ore, after passing between the rollers, is guided by a trough into D, (fig. 13) a cylindrical rotating sieve inclined about 1 in 8, covered with wire-work of the requisite size. This allows the mineral, when sufficiently crushed, to pass through, returning larger particles to the raff-wheel B, which elevates them to a shoot, conveying them to the hopper A again, to be re-crushed. (See fig. 13, & also fig. 4.)

Only one laborer is required for this machine for a shift of 4 hours to crush 20 tons. About 10 horse-power is required. One set of chilled rolling surfaces will crush 7.500 tons of ore, representing 6 months.

[Spon's Dictionary of Engineering, Article Ores.]

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The crushed and carefully sized ore is now ready for roasting. It should be so arranged that the crushed ore falls out of the griddle on an inclined plane which leads to a charging floor directly above the roasting furnaces. (See fig. 13.)

The roasting is for the purpose of freeing the ore from all the sulphur possible without too great expense. The last traces of sulphur it is impossible to drive away without too great a consumption of fuel and a loss of zinc. The roasting requires great care and thorough stirring of the ore, the purpose being to burn off the sulphur of the ore by heating with free access of air, according to the formula

$$ZnS + 3O = ZnO + SO_2$$

But at the same time a quantity of sulphate of zinc is formed, —

$$ZnS + 4O = ZnSO_4.$$

To decompose this, we increase the heat, to drive off sulphurous acid and oxygen from the zinc sulphate, leaving behind simply oxyd of zinc, ZnO. A little highly basic sulphate of zinc is always left undecomposed.

The oxide of zinc may then be reduced in the retorts. It seems that, when treating blende, the only way possible to get a good zinc is to introduce into the retorts the oxide of zinc as pure as possible.

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which can only be decomposed at something like a white heat, with a waste of fuel and a loss of zinc. The best practice under ordinary circumstances loses 1 to 2 per cent. of sulphur in the charge.

In this roasting also, some of the zinc is unavoidably carried off as oxide. For the purpose of collecting this, the flue from the roasting furnaces should lead to condensing chambers, where most of the oxide may be deposited.

The furnaces commonly in use for roasting are the two- and three-hearth reverberatories, the hearths being either directly one above another, or arranged end to end, each successive one from the fire-box higher than the last. These furnaces are not costly in erecting, but are very slow in working, so that in hardly any of them can more than 2 to 3 tons be roasted in 24 hours. They have the objection, too, of requiring continuous skilled labor of the hardest kind in stirring.

The furnace I have chosen for this purpose is the Brückner cylinder furnace, arranged with a reverberatory furnace. (See figs. 9 & 10) I am aware that there are objections to this furnace, not the least of which is the consumption of the iron of the diaphragm by sulphur. And the machinery may be displaced by expansion due to heat. But these objections can certainly be done away with — the first, in part, by substituting tile-plates of fire-clay instead of iron between the tubes

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The "Transactions of the American Institute of Mining Engineers," Vol. II, p. 295, is my authority for using the Brückner Cylinder for zinc ores. Such a furnace as is there described I have adopted with little change, in connection with a reverberatory, for roasting the blende. (See fig 9.) The dimensions I have used are the same as those given below. I have placed the cylinder immediately above the reverberatory, connecting with it by a short vertical flue, which turns the draft 180°. The same fire is used for both furnaces, thus utilizing what would otherwise be waste heat from the reverberatory. The preliminary roasting is done in the cylinder with the low heat; the most of the sulphur can be driven off in the cylinder with the advantage that the stirring is done by steam power. The ore is then raked into the reverberatory and subjected to intense heat, while a fresh charge is placed in the cylinder. In short, the cylinder takes the place of the second and third hearths in the old

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blende-roasting reverberatories, with the advantage of automatic stirring.

In the volume of Transactions above referred to, the following description is given of the Brückner cylinder.

"The exterior of the cylinder is a shell of boiler iron, 12 feet long by 5 ft. 6 in. in diameter. The ends are partly closed with similar material, having in the center a circular opening about 2 feet in diameter, bounded by a flange projecting several inches. Upon one side is placed an opening closed by a hinged door, upon the outside of the cylinder are bolted three bands, (as shown in fig. 9) in which the section of the first is square, and that of the third semi-circular; the second, or middle band, is a strong spur gear. Passing through the cylinder are 6 pipes parallel to one another, in a plane at an angle of 15° with the axis of the cylinder; these pipes also lie in this plane at an angle of from 30° to 35° to the longitudinal axis of the plane, (as shown in fig. 9); a perforated diaphragm being formed through part of the cylinder by means of perforated plates placed between the above-described pipes, the plates being held in place by longitudinal grooves upon these pipes. The entire cylinder is lined with fire-brick, which are placed in the following manner:— The entire side of the cylinder is covered with one layer, laid flat-wise, thus forming a lining about 2½ inches thick. There is an

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"The cylinder is supported upon four large friction rollers, two of which are grooved upon their periphery to fit loosely the semi-circular band, thus holding the cylinder longitudinally in place. The other two friction rollers are made without a groove, and bear upon the square band, thus accommodating themselves to the expansion and contraction of the cylinder, or any irregularities of form. Rotary motion is given to the cylinder by means of a pinion placed under the cylinder, and gearing into the spur gear band. Upon the other end of the pinion shaft are placed two bevel wheels, into which gear two match wheels. The latter are loose upon the driving shaft, at right angles to the pinion shaft; and either of these wheels can be attached to the driving shaft, thus communicating the speed of the revolution to one or the other of the bevel gear, as may be desired. Inasmuch as by wear or by settling, the axis of the cylinder may be thrown out of the proper

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"The circular flange of one end of the cylinder loosely projects into a fire-box. (Into a flue in our figure 9.) The other end projects into an opening communicating with dust-chambers and a chimney. There is placed in the bottom of the flue a shoe projecting into the cylinder, which catches such dust as may fall back, and returns it into the cylinder in lieu of allowing it to escape through the crevice between the cylinder flange, and the opening into the flue. A door is placed in the flue opposite the opening, through which the interior of the cylinder and its contents can be readily examined at any time.

"The fire place is 5 by 2 feet; height of roof, 2 ft; roasting cylinder, 5 ½ feet in diameter and 12 feet long; thickness of lining, 6 inches."

This is the description of the furnace as manufactured by Lane, Bodley and Company of Cincinnatti for the chloridizing roasting of silver ores, for which purpose alone it has thus far been used.

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Only 4 tons of coal would be required at most for roasting 10 tons of blende.

The supports for the cylinder should of course be of a very strong & stable character.

The reverberatory furnace, since it is meant to hold a charge of two tons, should be, in order to have something like the same proportion of hearth area to the weight of charge as is used in Wales, about 18 feet long & 10 feet wide. This gives 180 sq. ft for 4000 pounds, or 22 pounds per square foot. On the furnace drawn, (Figs. 9 & 10), the firebridge is 2 ft. 4 in. high. The middle of the arched roof is 3 ft. 4 in. above the hearth and 1 ft. at the end. The roof is provided with an opening 1 ft. square for receiving the charge from the cylinder above. The flue at the end of the furnace leads into a vertical flue built of brick and lined with fire-brick, into which opens the end of the Brückner cylinder. This flue should have two openings from the reverberatory furnace, -(fig 10, BB.), 12 inches by 24 inches each. The flue is 4 ft. long by 18 inches wide, and leads directly into the Brückner Cylinder.

The reverberatory, which must have this large size on account of the capacity of the cylinder, should be built of stone or red brick, and lined with two or three

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The hearth should be made of firebrick laid in a fire-clay mortar.

The furnace should have 4 work-doors on each side, 14 inches wide and 10 inches high on the inside, and 20 inches wide and 12 inches high on the outside. These doors should be 3 ft. apart on the inside, and are made for access to the ore for stirring. They should be closed by swinging or sliding iron doors, when not open for the purpose of stirring, to prevent cooling the inside of the furnace The openings next the firebox are used for discharging the ore when roasted.

The reverberatory connects by the flue mentioned, which is 8 ft. high, with the Brückner cylinder. This is placed just above the reverberatory, having an interval of two feet between the exterior wall of the reverberatory and the shell of the cylinder. The cylinder connects with this flue by a circular opening 2½ feet in diameter, which gradually enlarges until it reaches the conical end of the cylinder proper, which is the frustum of a cone with a base 5 ft. 6 in. in diameter, upper base 3 ft. in diameter, and altitude, 6 inches. The cylinder is then exactly as described.

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Work doors in the side of the cylinder may also be added if found necessary for transferring.

The cylinder is 12 feet long. The other end communicates with condensing flues (C) for the purpose of saving most of the zinc oxyd carried out by the draft. These flues must not cost much, as the oxyd lost is not of great value; nor must they be too extensive, else they will interfere with the draft. As shown in my plan, they are simply a set of chambers connecting by openings alternately arranged on opposite sides, the partitions extending not quite across. The chambers are nine ft. high, 13 ft. wide, and 8 ft. long in direction transverse to that of the length of the furnace. They are four in number, as shown in the figure. They may be built of red brick, the outer wall of three bricks thick, the inner partitions two bricks thick. The last chamber communicates with the stack, which is of red brick, 50 ft. high, with a section 4 ft. square at bottom, x 2ft. square at top, inside the bricks.

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a floor at the upper level of the cylinder. When it is desired to charge the cylinder, it is stopped with the opening upwards. The draft in the furnace is shut off at the firebox. The cap is taken off, and the ground ore is shoveled into the hopper above the opening from the pile on the floor. At the same time another workman with a long rake spreads the ore evenly over the diaphragm, working through the opening A in the flue at the front of the cylinder. When two tons of blende have been thus charged the opening is closed; and the fire in the fire-box being urged, the cylinder is revolved at the rate of about 1 turn per minute. The revolution, with the inclined perforated diaphragm D causes the heated ore to traverse alternately backward & forward the entire length of the cylinder, also sifting it through the flame, thus insuring a uniform heating, mixing, & exposure to chemical action; The diaphragm, in the mean-time, is protected from destructive action of heat by the cooling effect of the external air circulating through the pipes.

After 8 hours, by which time most of the SO_2 will be driven off, there will remain a mixture of ZnO, ZnS, & $ZnSO_4$. The cylinder is then stopped with the opening E downwards, so as to communicate directly with the opening in the top of the reverberatory by means of a hop

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In the reverberatory the ore is spread out and submitted to a red heat, with constant stirring, for eight hours. The intervals between the stirrings should not exceed 20 minutes. If by eight hours no more SO_2 is given off, the ore may be raked out gradually at the workdoors nearest the firebridge, into iron barrows, which convey it to the mixing sieves (Fig 13, K.) for mixing with coals.

After the cylinder has been discharged into the reverberatory, it is turned with the opening upwards, recharged, and revolved as before for eight hours more.

The amount roasted thus by a single compound furnace of this character would be, if the estimates are correct, 6 tons per day, each two tons being roasted 16 hours.

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30. In European furnaces, two tons are roasted in common reverberatories 18 to 20 hours, and I think the time has not been under-estimated when we consider the improvement made by introducing the Brückner. In the West, ores with 15 to 20 % blende & galena are completely roasted in charges of two tons altogether in the Bruckner, (and consequently without exposure to such heat as may be obtained in the reverberatory) in 15 to 20 hours, including chloridizing, — using only 3/4 cord of wood or 3/8 ton of coal per day.

The fuel required, taking as a basis of calculation the roasting furnaces of Borbeck in Prussia, and also the amount used in Wales at Llansamlet, together with the amount of coal used per day in the Brückner cylinder in the West, will not be over 2 1/2 tons flaming coal per day. 5 tons roasted ore, = 6 tons raw ore, requires 70 cu. ft. = 2 tons of coal at Borbeck.

The labor will be two men each shift of
1 eight hours, or 6 men per day.

The reverberatory will cost $2500. The Bruckner cylinder can be obtained of Lane & Bodley at Cincinnatti, f.o.b. for $1600. The cylinder & attachments weigh 8 tons.

The following is the average cost of roasting, for one day.

In European furnaces, two tons are roasted in common reverberatories 18 to 20 hours, and I think the time has not been under-estimated when we consider the improvement made by introducing the Brückner. In the West, ores with 15 to 20% blende & galena are completely roasted in charges of two tons altogether in the Brückner, (and consequently without exposure to such heat as may be obtained in the reverberatory) in 15 to 20 hours, including chloridizing, --using only ¾ cord of wood or ⅜ ton of coal per day.

The fuel required, taking on a basis of calculation the roasting furnaces of Borbeck in Prussia, and also the amount used in Wales at Llansamlet, together with the amount of coal used per day in the Brückner cylinder in the West, will not be over 2 ½ tons flaming coal per day. 5 tons roasted ore, = 6 tons raw ore, requires 70 cu. ft. = 2 tons of coal at Borbeck.

The labor will be two men each shift of eight hours, or 6 men per day.

The reverberatory will cost $2500. The Brückner cylinder can be obtained of Lane and Bodley at Cincinnatti, f.o.b. for $1600. The cylinder and attachments weigh 8 tons.

The following is the average cost of roasting for one day.

6 days labor @ 3.00	18.00
*Labor for engine, 1 day @ 2.50	2.50
2 1/2 tons coal @ 3.75	9.38
*30 h. p steam 8 hours = 1 1/4 tons coal	1.56
†Wear & tear of furnaces, & interest	2.97
†Interest & wear & tear of engine	.67
	$35.08

or, counting 6 tons roasted per furnace per day, $5.84 c. p. ton.

* The engine here is only counted for 1/3 of the time, since probably not more than 1/3 of the power of the engine would be employed on the cylinder,, but on other work.

† The furnaces are calculated to duplicate their cost in seven years, the engine in ten years.

The ore, after raking out of the roasting furnaces & cooling, is next ready for the operation of distilling.

6 days labor @ 3.00	18.00
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2 ½ tons coal @ 3.75	9.38
*30 h.p. steam 8 hours -1 ¼ tons coal	1.56
†Wear & tear of furnaces and interest	2.97
†Interest & wear & tear of engine	.07
	$35.08

or, counting 6 tons roasted per furnace per day, $5.84 c. pr. ton.

*The engine here is only counted for ⅓ of the time, since probably not more than ⅓ of the power of the engine would be employed on the cylinder, but on other work.

†The furnaces are calculated to duplicate their cost in seven years, the engine in ten years.

The ore, after, raking out of the roasting furnaces & cooling, is next ready for the operation of distilling.

Distillation.

No improvements have been made in the distillation of zinc within the last 40 years. The method I have adopted for this purpose is the Belgian retort method, this being the one most nearly suited to the economical conditions of this country. I have adopted the Lehigh works at Bethlehem, Pa., as the most satisfactory model, with improvements where possible.

The distilling is done in fire clay cylinders (Fig. 5 & 6) or retorts, 42" long, 9" in diameter outside, 6" inside, with the closed end 2¼" thick. These are made at the works of a mixture of fresh fireclay and ground fragments of old retorts. The mixture used at Engis is 30 parts raw clay, 27 chamotte, 18 coke, 15 old retort, and 10 sand, mixed with water & carefully kneaded. The retort is built up like a circular tower by winding spirally around its outer edge a succession of long rolls of the plastic clay. The proper drying requires months, the longer the better. It is performed in large heated chambers. The retorts are highly heated just before use, and are introduced glowing into the furnace.

A retort costs about $2.50, including condensers and prolongs. They last for 28 charges, or two weeks, on an average.

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A retort costs about $2.50, including condensers and prolongs. They last for 28 charges or two weeks on an average.

The retorts are provided with fireclay nozzles or condensers (Fig. 7) over the outer end of which conical tubes or "prolongs" of sheet iron (Fig. 8) are placed during the operation.

The receivers or condensers are of coarser fireclay than the retorts, with the following dimensions:—

Diameter at base,	4 1/2 inches
Diameter at top,	1 1/2 inches
Perpendicular height	16 inches.
Thickness of walls,	3/4 inches.

The capacity of the retort is about 1200 cubic inches. The capacity of a receiver is about 75 cubic inches, or 1/16 that of a retort.

The furnace used is shown in figs. 11 & 12.

I have introduced instead of the common fireplace, a Boetius gas producer. (Fig 12, A.) Siemens' regenerating furnaces have been tried for this purpose, but do not work so economically as the more simple gas-producer named. This gives a high even heat easily controlled. It is a matter of importance that the gases of the distilling furnaces should not be utilized for heating purposes, since that would interfere with the proper regulation of the heat.

The Boetius gas producer is shown in section in figure 12 of the zinc furnace. It consists of a chamber A, 5 feet high, 1 ft. 8 in.

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The receivers or condensers are of coarser fireclay than the retorts, with the following dimensions:--

Diameter at base	4 ½ inches
Diameter at top	1 ½ inches
Perpendicular height	16 inches
Thickness of walls	¾ inches

The capacity of the retort is about 1200 cubic inches. The capacity of a receiver is about 75 cubic inches, or 1/16 that of a retort.

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The Boetius gas producer is shown in section in figure 12 of the zinc furnace. It consists of a chamber A, 5 feet high, 1 ft. 8 in.

wide at the bottom, and 4 ft. 8 in. wide at the arch. The coal for burning is supplied at D, & slides down the inclined plane B to the grate G. The coal is ignited at the grate and is heated to different degrees, a portion being converted into hydro-carbon gases and vapors, in the same manner as in a gas retort. Another portion, answering to the coke, principally combines with the oxygen of the air and forms carbonic acid. In rising through the incandescent coal it is reduced to carbonic oxyd. The hydrogen, hydrocarbon gases and carbon monoxyd, meeting a stream of warmed air from C in E, burn immediately with an intense even heat, which is easily regulated by dampers.

A furnace with one of these producers requires only 3/4 as much coal as is required in a common fire-place.

The distilling furnaces are built in groups of four, the internal walls being entirely of firebrick, and the external ones of common brick, lined with firebrick. Each separate furnace is a chamber of rectangular section, with a semi-cylindrical arch above. In Belgium the furnaces are eight feet eight inches from the highest point of the arched roof to the floor, the back of the chamber being constructed so as to recede

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At the Lehigh works, 56 retorts are placed in each furnace in seven rows, eight retorts being in a row. In the estimate given in this problem for treating 20 tons, it is found necessary to use 8 furnaces holding 80 workings retorts each. It is more common among the later furnaces to use a larger number of retorts than was used at first.

Beneath the retorts is placed a row of six so-called “cannons” to break the heat. These are three ft. four inches long, and seven inches in diameter outside, and are not charged. The retorts rest at the back on ledges of masonry (Fig 11, A) and at the front on plates of firebrick 24 inches long, 9 ½ inches broad, and 2 inches thick, supported by vertical firebrick pillars 11 inches high. The walls of each furnace inclose a space 8ft. 3in. by 2 ft. 6 in. the interval walls being about 18 in. and the side walls 2 ft. 6 in. thick.

The slant at which the retorts are placed should be about 3 to 6 inches for this ore, from back to front.

The furnaces have a framework of cast-iron to add strength, and flat iron plates are placed in front of the retorts, to support the condensers, ladles, etc.

The products of combustion pass out by double flues, (fig. 12, I) into the stack, one stack doing duty for each block of four furnaces.

The cost of a block of four of these distilling furnaces, built as described, is $5000.00. (Trans. American Inst. of Mining Engineers, Vol. I, p. 74.)

The roasted blende from the reverberatory furnaces is now mixed with fine coal, in amount 40 % of its weight The coal which is used is the Spadra non-caking semi-anthracite, of Arkansas, before described. This, if not procured already in the form of dust, must be crushed so that it will pass through a sieve of 100 holes to the square inch, The roasted ore & coal are thrown on a vibrating sieve, with 10 holes to the linear inch, having been previously weighed If the workman throw on an equal number of shovels of roasted ore and of coal, almost exactly the correct proportions will be given. The ore & coal in passing through the sieve are thoroughly mixed, and the mixing is completed by subsequent shoveling.

The sieve should be about 6 ft. square, made

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of iron. Motion may be communicated by means of a connecting rod and crank, the sieve being controlled by guides. One laborer is required to operate.

The ore is now ready for charging in the retorts.

Before placing the retorts in the furnace, a brisk fire is maintained in it for some time, so as to bring the interior to a bright red or white heat, the face of the furnace being built up with bricks or fragments of broken retorts. When this condition has been attained, the cylinders, which have previously been heated to redness in a reverberatory, are fixed in their places one by one, the interstices between the retorts at the front being closed up with fire-clay. At first a small quantity of ore with coal is submitted to reduction in the cylinders, the condensing cone & prolong attached and luted, and any metal given out collected in ladles. These preliminary charges are increased for three or four days, when the normal charge is attained.

Forty pounds of the mixture of coal and roasted ore are now introduced into each retort. This is done by means of a long half-cylindrical shovel attached to a long iron handle; commencing with the lower retorts, and proceeding to the higher ores in succession.

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The ore is now ready for charging in the retorts.

Before placing the retorts in the furnace, a brisk fire is maintained in it for some time, so as to bring the interior to a light red or white heat, the face of the furnace being built up with bricks or fragments of broken retorts. When this condition has been attained, the cylinders, which have previously been heated to redness in a reverberatory, are fixed in their places one by one, the interstices between the retorts at the front being closed up with fire-clay. At first a small quantity of ore with coal is submitted to reduction in the cylinders, the condensing core & prolong attached and luted, and any metal given out collected in ladles. These preliminary charges are increased for three or four days, when the normal charge is attained.

Forty pounds of the mixture of coal and roasted ore are now introduced into each retort. This is done by means of a long half-cylindrical shovel attached to a long iron handle; commencing with the lower retorts, and proceeding to the higher ores in succession.

The lower retorts are charged with the richest ore, while the oxide and scrapings obtained from previous operations are charged in the upper retorts. These upper retorts are charged only once in 24 hours.

After charging the retorts the condensers are luted in place so as to lie horizontally, and the heat is increased.

As soon as oxide of zinc is seen burning at the ends of the condensers, the prolongs of sheet iron are put on to save the escaping zinc.

<u>Chemistry.</u>

The reactions which take place in the retort are as follows:—

The air introduced with the charge causes an imperfect combustion of a portion of the carbon present, forming carbon monoxyd, which reduces oxide of zinc to the metallic state by taking oxygen from it, and forms carbon dioxide, CO_2. We have present in the retort, at a high temperature, oxide of zinc, carbon, and carbon monoxide. By the reduction of two atoms of zinc to the metallic state, one atom of carbon monoxide is converted into carbon dioxide; and one atom of carbon into carbon monoxyd; and so the process goes on, continually repeating itself until the contents of the retort are exhausted. The following formula shows the reaction:—

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$2\,ZnO, + C + CO = CO_2 + CO + 2Zn.$

Since zinc volatilizes at a degree of heat required for the reduction of zinc oxide, (the temperature required for reduction is °1300 c, – that of vaporization is °1200 c) it follows that the reduced zinc is in a state of vapor. In this state, and at a little below the proper temperature for reduction, it is very easily oxidized by CO_2, according to the reaction

$$Zn + CO_2 = ZnO + CO,$$

forming zinc oxide, which is wasted; or treated a second time after collecting in the prolongs. If much water is present, zinc powder is formed, which seems to be finely divided zinc partially oxidized. The condensers must be kept so cool that the zinc will at once become liquid.

The temperature in the furnace should be kept above 1300°, or the fusing point of cast iron.

The time required for working one charge is twelve hours, excepting the top row containing oxide, skimmings, powder, dust, etc., which are allowed to remain in 24 hours.

At the end of 12 hours the prolongs are taken off, the oxide collected, and the zinc from the condenser collected in ladles and poured into molds. The retorts are raked out and thoroughly cleaned, a fresh

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charge is introduced, the condensers luted on, and the process continued. A row of condensers can be emptied in ten to fifteen minutes.

Of the 40 lbs. charged into a retort, 24 lbs. is roasted blende, of which about 67.75 %, or 16.8 lbs. is zinc. Of this, about 70 % is the <u>direct</u> yield (though 12 % only is total waste) or 11.39 lbs. per retort per 12 hours. Part of the 30 % remaining is saved by treating skimmings, oxide, etc., over. The total wastage at Carondelet, is, as stated above, 12 % of the zinc produced; the waste being in the form of skimmings, drippings, dust, etc.

The number of men required per furnace per 24 hours is 9.

About 2½ tons of coal for fuel per furnace will be required in 24 hours.

2560 pounds non-caking coal will be required per furnace per day, if 80 retorts are used, as reducing agent.

18.6 cwt. zinc will be produced per furnace per day.

Wear and tear of furnaces, counting the cost added to itself each 18 months, is about $4.00 per furnace.

After collecting in ladles, the zinc is skimmed, and then is poured in molds 7 inches X 24, and one inch deep, forming ingots which weigh 40 to 45 lbs. The

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skimmings are retreated. ——

The zinc is allowed to cool slowly and thus a crystallized appearance is produced which makes the product sell more easily.

In the succeeding pages is given the estimate of production of zinc per pound, by items.

In the drawings which follow, the following colors are used to designate the material the name of which stands opposite: —

Brick red, —	common brick
Ochre, —	fire brick.
Reddish ochre, —	wood.
Blue —	iron.
Gray, —	india rubber.
Slate, —	earth.

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Gray india rubber
Slate earth

In the following calculation of cost, 1 horse power per hour is estimated at 4 lbs. of coal.

The cost of the Blake Crusher is put at $1000, and it is calculated to last three years.

The crushing rolls & attachments are calculated to cost $500 p. year.

The griddle & raff wheel is estimated at $300 for two years.

The cost of roasting furnaces is put at $4000 p. furnace each 7 years.

The engine cost is put at $3000 for 10 years.

Eight distilling furnaces cost $5000.00 each 18 months.

The wastage on retorts is 59 c. per 100 lbs.

All interest is calculated at 10 p. c. per annum.

Cost of treatment per cwt. of zinc. After delivery at works. Estimated for works treating 20 tons of ore daily.

Crushing. – Blake's Crusher		
Labor, 1/4 day @ 2.00		50
Steam power, 10 horse power 2 hours, = 80 lbs coal		14
Interest and wear & tear of crusher	1	30
Crushing – Rolls.		
Labor, 1/2 day,	1	00
Steam-power, 10 h. p. four hours,		28
Interest & wear & tear of rolls	1	40
Carried forward	4	62

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The wastage on retorts is 59c. per 100 lbs.

All interest is calculated at 10 pr. c. per annum.

Cost of treatment per cwt. of zinc. After delivery at works. Estimated for works treating 20 tons of ore daily.

Crushing – Blake's Crusher		
Labor, ¼ day @ 2.00		50
Steam power, 10 horse power 2 hours = 80 lbs coal		14
Interest and wear & tear of crusher	1	30
Crushing - Rolls		
Labor, ½ day,	1	00
Steam power, 10 h.p. four hours		28
Interest & wear & tear of rolls	1	40
Carried Forward	4	62

Brot. forward,	4	62
Griddle & Raff-wheel.		
3 h.p. per hour, 4 hours,		08
Interest & wear & tear,		40
Roasting 20 tons ore.		
18 days labor @ 3.00 (for 3 furnaces)	54	00
Labor for engine, 3 days, @ $2.50	7	50
7½ tons coal @ 3.75,	28	15
30 h.p. steam, 24 hours	4	69
Interest & wear & tear of furnaces,	8	90
Interest & wear & tear of engine,	2	00
Conveying to mixers.		
3 days labor @ 1.25	3	75
mixing, 1 day @ 1.25	1	25
Wear & tear of Griddle, & steam,		20
Distilling.		
Labor for 8 furnaces, 72 days @ 3.00	216	00
Fuel, 20 tons caking coal @ 3.75	75	00
9 tons Spadra coal @ 5.00	45	00
Interest & wear & tear of furnaces & tools,	31	00
Wastage on 640 retorts @ 59c. per 100 lbs. zinc,	99	12
Rent on building ($4000, 10%, 1 day)	1	08
Superintendence (@ 2500 p. year,) 1 day	6	84
	$589	58

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Interest & wear & tear	|40
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Interest & wear & tear of furnaces	8|90
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From 20 tons raw ore we produce 148.7 cwt. zinc, or about 300 lbs. raw ore = 1 cwt. Spelter, or 1/7 ton = 1 cwt. Spelter. At the present price of spelter, it appears that zinc can be made profitably when paying $15.00 p. ton for blende. Spelter is now worth 6½ – 7 c. per lb. The amount of spelter produced given above does not include that recovered from residues.

L. R. Grabill.

Missouri School of Mines & Metallurgy,
June 1, 1878.

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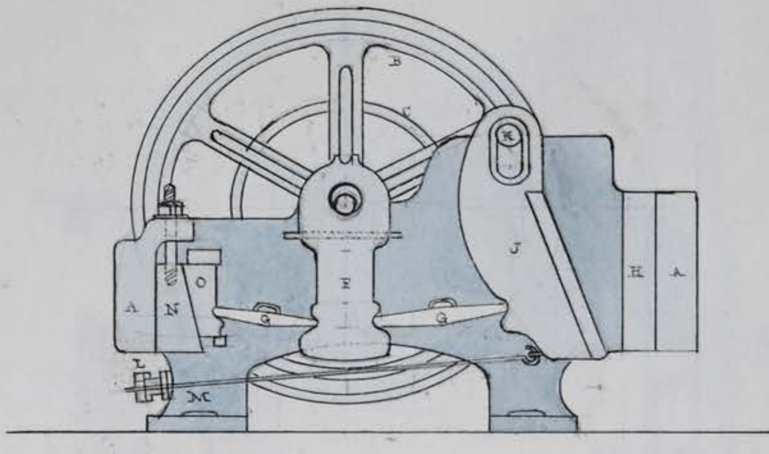


Fig 1.-Blake Crusher.

Scale, 4/10 in. = 1 ft.

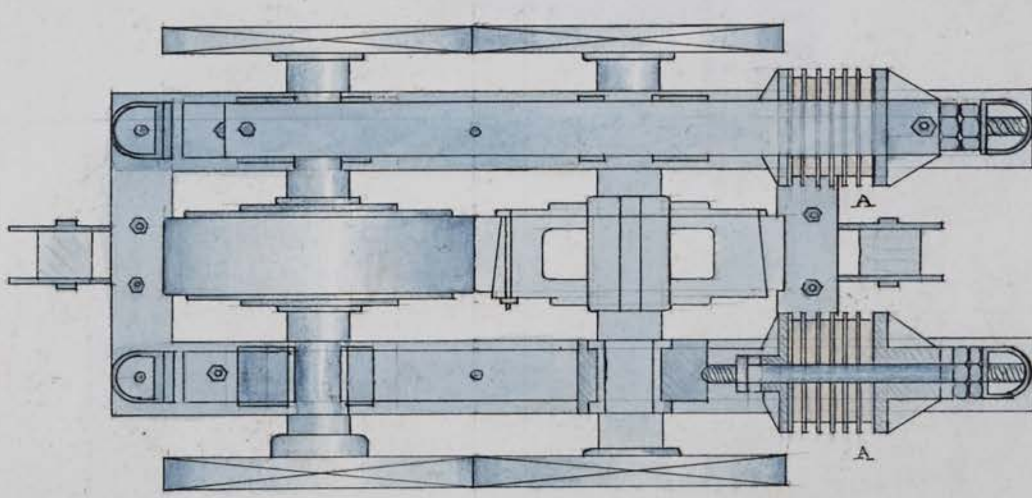


Fig. 2.-Crushing Rolls-Plan.

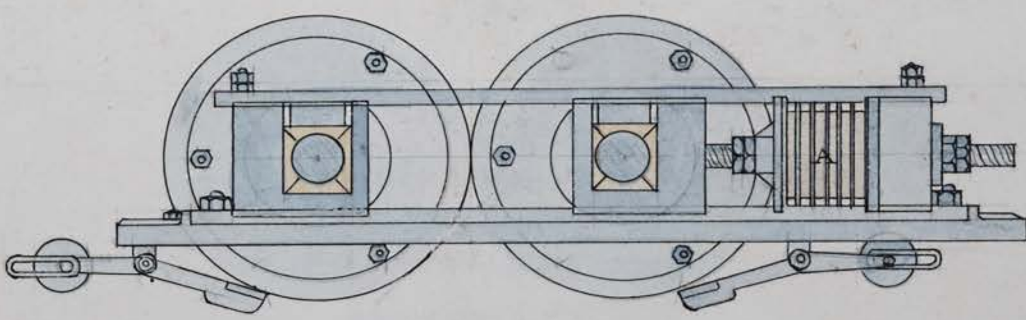


Fig 3.-Crushing Rolls.

Scale, ½ in. = 1 ft.

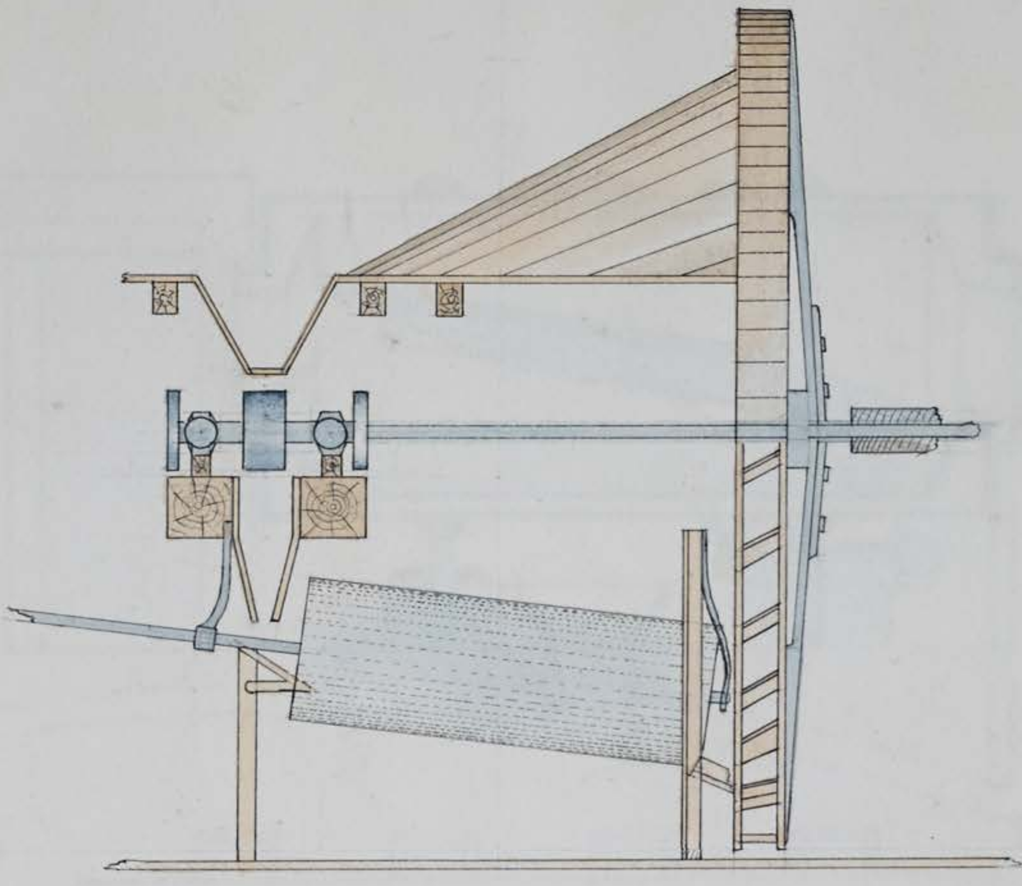
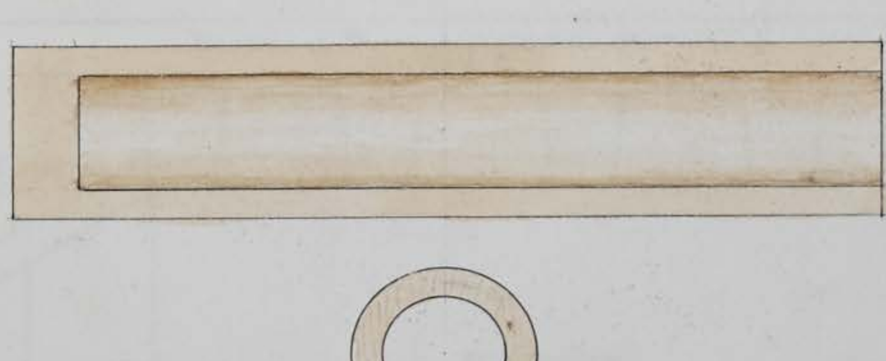


Fig. 4.—Elevation of Griddle, Raff-wheel, and Crushing Rolls.

Scale, 1/4 in. = 1 ft.

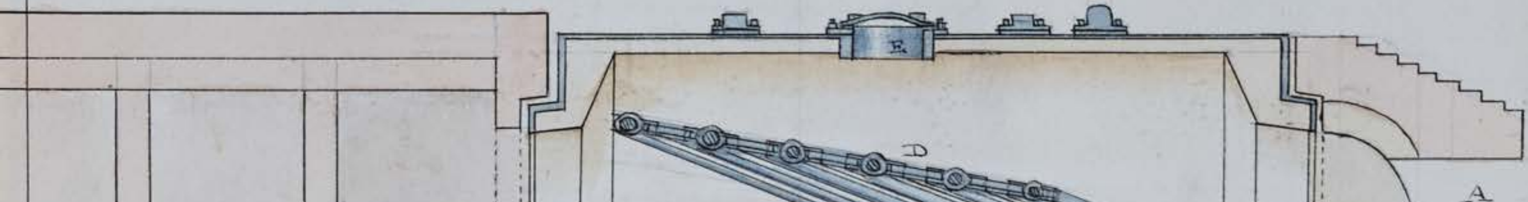


Figs. 5 & 6, Sections of Clay Retort.

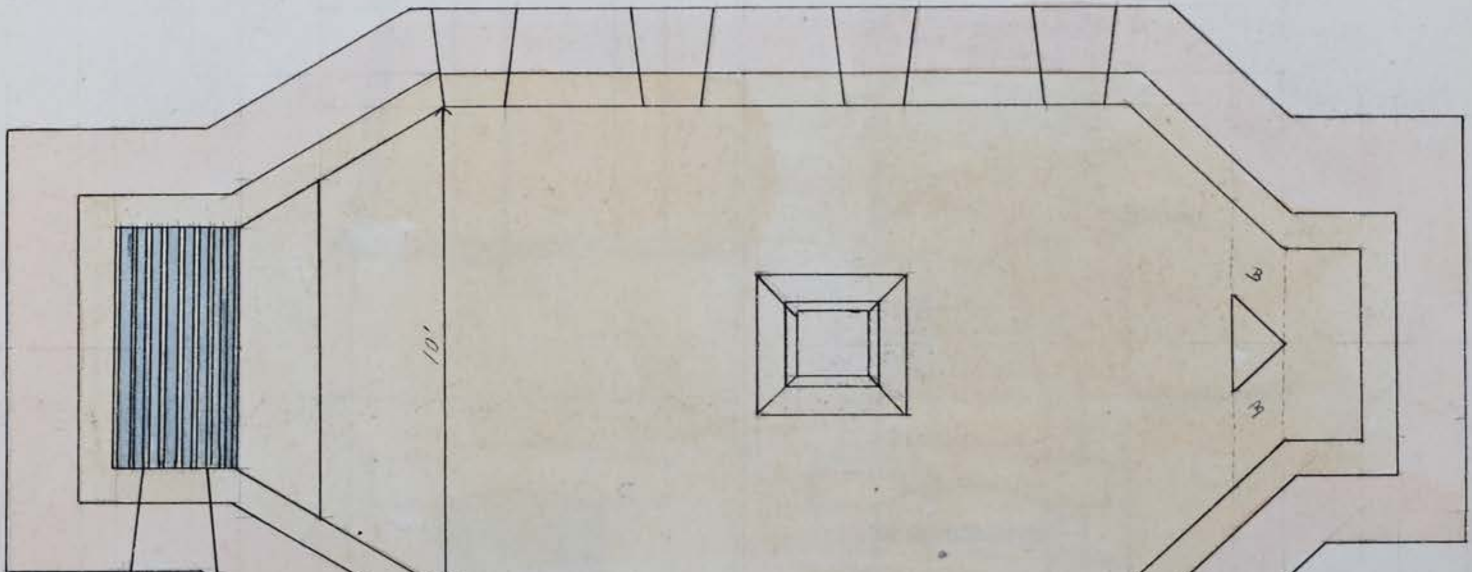
Fig. 7 — Condenser.

Fig. 8 — Prolong.

Scale, 6/5 in = 1 ft.



Roasting Furnaces - Vertical Section.
Fig. 9.



Roasting Reverberatory - Plan.
Fig. 10.

Scale, 1/4 in. = 1 ft.

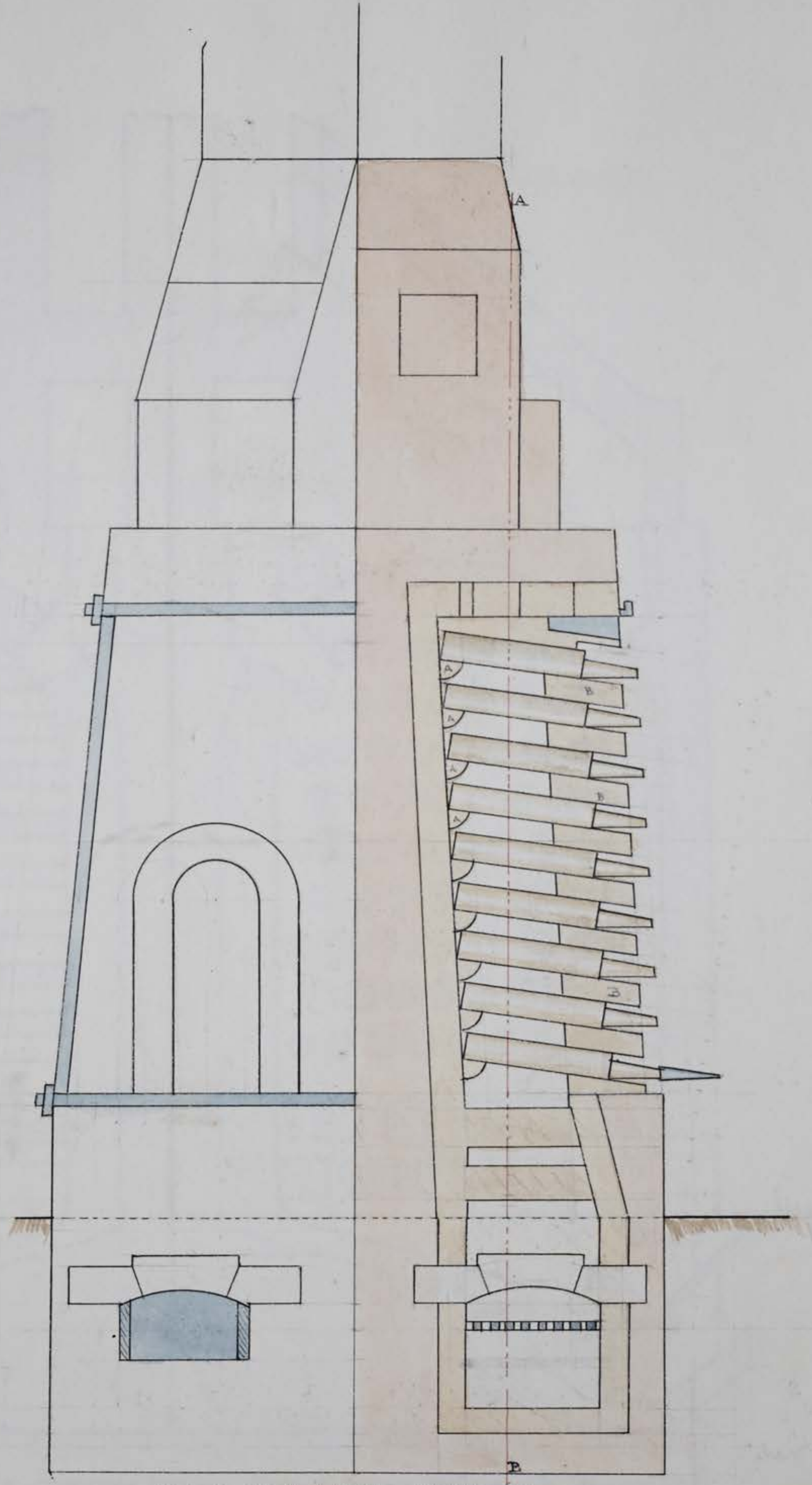


Fig. 11.–Vertical Section Distilling Furnace.
Scale, 1/4 in. = 1 ft.

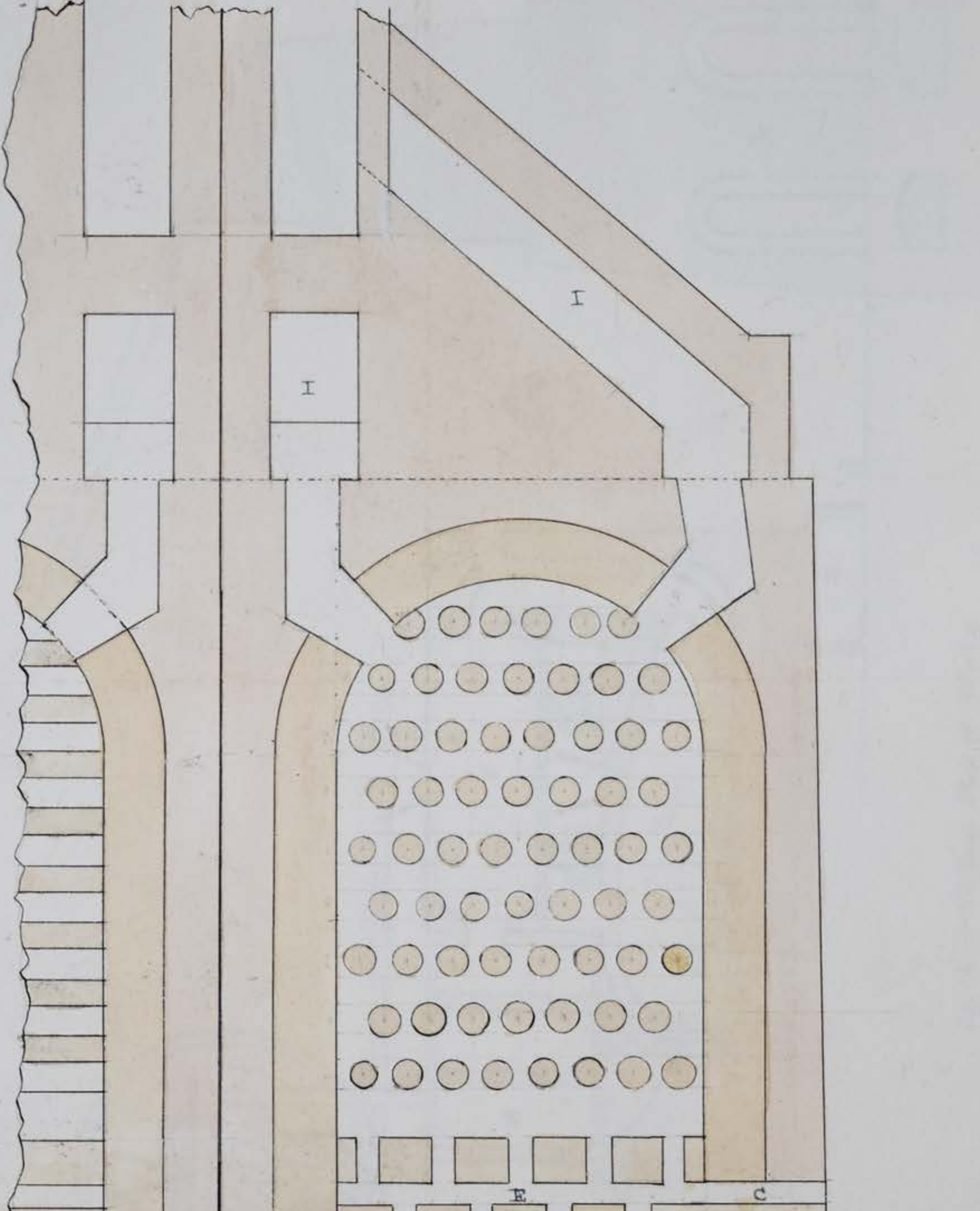


Fig. 12 – Distilling Furnace – Vertical Section on Line AB, Figure 11.

Scale, 1/4 in. = 1 ft.

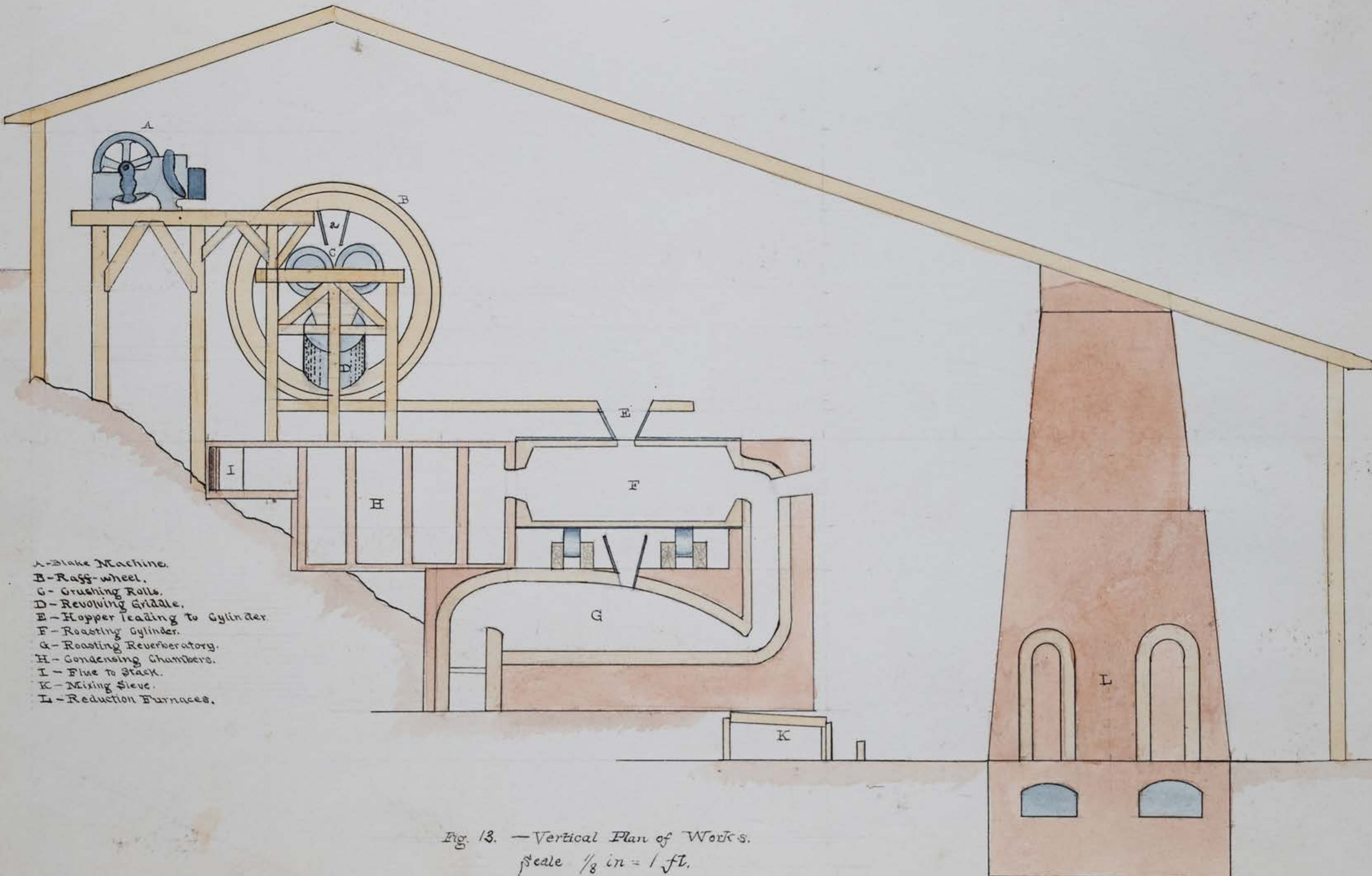


Fig. 13. —Vertical Plan of Works.
Scale 1/8 in = 1 ft.

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